VOLUME 79 SEPARATE No. 307

PROCEEDINGS

AMERICAN SOCIETY
OF
CIVIL ENGINEERS

OCTOBER, 1953

SEWAGE AERATION PRACTICE IN NEW YORK CITY

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Presented at
New York City Convention
October 19-22, 1953

SANITARY ENGINEERING DIVISION

(Discussion open until February 1, 1954)

Headquarters of the Society
33 W. 39th St.
New York 18, N. Y.

PRICE $0.50 PER COPY

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This paper was published at 1745 S. State Street, Ann Arbor, Mich., by the American Society of Civil Engineers. Editorial and General Offices are at 33 West Thirty-ninth Street, New York 18, N. Y.

SEWAGE AERATION PRACTICE IN NEW YORK CITY

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The program today includes discussions of the aeration practices in Chicago and in New York City. At the outset I would like to make it clear that our early practice here in New York was based on the excellent works then developed in Chicago. Our first aeration plant at Wards Island was modeled largely on the Chicago works and was developed with the advice and assistance of those most familiar with the practice there. We were fortunate in its initial operation to secure supervisory personnel trained in Chicago and familiar with their operating practices. Wards Island has been a thoroughly successful plant. We acknowledge our indebtedness to the pioneering work done in Chicago.

Our work in New York City thus started on the sound basis of the Chicago practice. While this practice had been based on much experimental work, actual applications were somewhat empirical resting largely on practice and experience. It has been our effort here to break down the activated sludge process into its two major elements, first--the requirements for the maintenance of effective activated sludge and secondly--the requirements of removing sewage impurities by this effective sludge. We have also sought to develop means for intermediate treatment using aeration methods. In this endeavor we are fortunate in that our position on tide water permits some latitude in the degree of treatment so that the hazards of a bolder approach are not quite so great as they may be in some other places. On the other hand the desirability of furnishing high degrees of treatment, on sites that must of necessity be small and are in fact costly to develop, placed a premium on compact plants. Our efforts to simplify, improve and further explore the possibilities of activated sludge methods has resulted in three modifications of previous aeration practices which will be the chief theme of our discussion today.

The first, "step aeration" is a modification of complete activated sludge treatment which has been in use since 1939 and is now incorporated in six of our plants. The second, "modified aeration" or "high rate activated sludge," which provides an intermediate degree of treatment, has been in use since October 1943. It has been used at six of our plants, two of which have been designed for the use of this method only. The third modification, designated "activated aeration," is quite recent and also provides intermediate treatment. This method, which has been in use for somewhat less than a year, was devised by Abraham Chasick a sanitary engineer of our department, comprises parallel operation of a complete activated sludge unit with a high rate unit, the two being interdependent.

All three modifications have been tried out in parallel operation at the Wards Island plant for significant periods. At this plant the flow treated is 25% above the 180 M.G.D. for which it was designed but only one half the aeration tanks originally provided are in use. In other words, each of the three aeration methods to be discussed require but limited aeration tank capacities. Even for the highest degree of treatment one half of previously accepted standards appears to be adequate.

For convenience there is listed in Table I the aeration plants now operating in New York City.

It may be well at this point to outline the major elements of the three methods we have in use. The first--"Step Aeration" is a complete treatment process fully equal in end results to conventional activated sludge methods. It is used in much smaller tanks but with more positive controls. In this method, sludge returned from the final settling tanks is introduced, as usual, at the head end of the aeration tanks. As it flows through the aeration tanks settled sewage is added to it at several different points. After successive dilutions the aerated mixture passes to the final settling tanks. In our practice the aeration tanks usually have four passes, labeled for convenience A, B, C and D, and provision is made for the introduction of settled sewage at the head end of each pass. Where the tanks are heavily loaded the first pass contains returned sludge only and the sewage is distributed among the other three possible points of inlet as conditions of loading and sludge quality dictate.

Underlying this method is the concept of "sludge age" in which it is recognized that a fairly definite period of time is required to convert materials in sewage to an activated sludge of the desired properties, with the ability to attract to itself colloidal and soluble impurities and at the same time to have physical properties that will permit it to settle readily in the final tanks. Results analyzed from well operating plants throughout the country show almost without exception that conditions have been controlled so that the sludge age is generally in the range of 3 to 4 days. The yardstick used for this determination is the weight of dry suspended solids in the aeration tanks divided by the daily dry weight of the incoming suspended solids of the sewage. In normal sewages accretions due to the removal of soluable B.O.D. and colloidal matter is counterbalanced roughly by the aerobic destruction of solids in the tanks so that the average detention of solids in the system thus determined is reasonably valid. Basically this is a measurement of biologic time, expressed in days.

When activated sludge is held under air progressively longer than 4 days the tendency is toward deterioration of the effluent quality due to the breakdown of the floc. On the other hand, if the sludge is held for periods much under three days the effluent may have sparkling clarity but the floc gradually loses settling quality and finally goes overboard with the effluent.

With step aeration we keep exactly the same weight of activated sludge solids in the aeration tanks as would be required under conventional activated sludge methods--usually at a sludge age of some 3.5 days. Inasmuch as higher suspended solids concentrations are maintained at the head end of the aeration tank, stepping down to normal or less than normal concentrations at the effluent end, the average concentration of solids may be twice that common in conventional practice. This will explain why only one half the tank capacity may be required.

As to air use,the same biological sequence must be maintained. Total air used in step aeration, as in conventional methods, will vary with sewage characteristics--perhaps influenced by the amount of readily assimilable food and possibly related to filtrate B.O.D. We know that the greatest air demand occurs when activated sludge is fed with sewage. By spacing the points of sewage feeding and limiting the dose at each feeding point, air requirements are spread more uniformly throughout the tank. It would seem that this should improve biological conditions and air economy but this has yet to be demonstrated conclusively. Certainly air requirements are no more than with conventional methods. It has been demonstrated that only a brief period of contact of sewage with well conditioned activated sludge is required to remove sewage

impurities. It has been found that a 30 minute contact under aerator concentrations of 1,000 P.P.M. is ample.

The operating controls of step aeration are simple and flexible. These are the manipulation of the step inlet gates to control the 30 minute settling tests in one liter graduates of samples of the aerator effluent. The rate of return sludge normally should not be changed.

Final settling tanks are essential elements in the activated sludge process. Their ability to permit the return of sludge quickly and in a fresh state and to completely separate solids from the liquid are important in the results achieved. Our final tanks are set up to take advantage of sludge density currents so that settled activated sludge flows through them and is back in the aerator in about one half hour, preventing undue sludge deterioration. This 30 minute period of detention roughly corresponds to the 30 minute settling test referred to above. It can be shown that a 25% return of sludge based on sewage flow will remove 20% of the volume entering the final tank. If, therefore, the volume of sludge entering the final tanks, as measured by the cylinder settling test, is 20% or less, a 25% return of sludge is adequate. Maintenance of cylinder readings below 20% by varying flows at the step inlet gates becomes the means of assuring that there will be no build up of sludge in the final tanks.

Operating with a constant return of sludge in the amount of 25% of the sewage flow, aerator effluents must be maintained at a concentration that will produce a cylinder test somewhat less than the 20% cylinder reading which can be handled by the 25% return pumpage. Should the cylinder reading tend to increase it is only necessary to admit a greater proportion of the sewage toward the effluent end of aerator. This automatically reduces the effluent concentration and the more voluminous sludge as diluted now occupies no more space than did the former sludge of better settling index. This same operation immediately starts corrective measures. Shifting the flow toward the effluent end of the aerator increases the activated solids concentration toward the beginning, giving the sludge a longer detention period under air, which corrects for the loading condition that caused the original deterioration. As the sludge settleability is recovered and cylinder readings are further reduced, the original setting of the step gates can be restored.

Table II indicates how aerator effluent concentrations can be adjusted to correct for sludges of various density indices and at the same time maintain proper biological balance in the aerator. The example is for a four pass aerator having a 2.5 hour detention period based on sewage flow plus 25% return sludge. The total solids in the aerator are kept constant and provide a 3.5 day sludge age for applied sewage having 100 P.P.M. suspended solids. The first line in the table is, of course, conventional activated sludge with no step additions but with limiting conditions under which few would care to operate. The last mode of addition represents the old practice of sludge reaeration followed by a short sewage contact period. It would be for emergency use only because of its unbalanced air requirements. Few diffusion systems could satisfy the air demands of the last pass where the heavy initial demand of all the sewage is exerted.

Typical step aeration results are shown in Table III.

A second major development in aeration practice was originally named "Modified Sewage Aeration" and is sometimes known as "High Rate Activated Sludge." This process gives results intermediate to plain sedimentation and full activated sludge treatment. The desirability of such a process was noted in 1931 when our first report on general plans for sewage disposal for the city

called for treatment by "Partial Activated Sludge" at several locations. It was not, however, until 1940 that we were able to establish a pilot plant at Wards Island to explore the possibilities of intermediate treatment by aeration methods. This work, carried out by Dr. Lloyd R. Setter, is reported in the literature.

The "Modified" process was first tried out in full scale operation at our Jamaica plant upon its completion in 1943 and except for a few months operation under step aeration has been in continuous and successful use. Averages of results for the past 9 years show suspended solids removals of 80% and B.O.D. removals of 74%. Excess sludge was pumped to the digestors at 6.4% solids. Air use has been at the rate of 0.41 cubic feet per gallon. The plant has no primary sedimentation and is currently treating 53 M.G.D. with an aeration period of 1.5 hours.

Modified aeration has the same flow pattern as conventional activated sludge in that returned sludge from the final tanks and all of the sewage are introduced together at the head end of the aerator. The essential difference is that solids in the aeration tank must be kept at an unusually low level. In terms of "sludge age," as previously defined, aeration solids are kept at from 0.2 to 0.5 days age, depending upon sewage temperature and characteristics. This compares with the 3.5 days age usually required for the conventional activated sludge process.

Excess sludge resulting from the "modified" process is dense. It will ordinarily settle to concentrations ranging from 4 to 8% solids, depending on the method of operation, as compared to the 2.5 to 3.0% for the conventional activated sludge. In this generalization special thickening methods are discounted. The basis for this difference in density may lie in the fact that not sufficient time is allowed for the conversion of all organics to a true activated floc, that is, to the cells of living organisms. Herein too may lie the reason that air requirements are just about one half of that for the conventional processes.

The level of suspended solids carried in the aeration tank under different temperature and sewage characteristics will control the effectiveness of the process. The higher the solids can be maintained the greater will be the purification effected but if sufficient time is allowed for too great biological development the settling qualities of the sludge will be impaired, results deteriorate and the process becomes unworkable. In this connection it has been found that the presence in the sewage of readily assimilable food in large amounts, as indicated by high values of soluble B.O.D., may result in prolific growths of sphaerotilus and the impairment of settling quality. In the case of the Owls Head sewage where the soluble B.O.D. is from 50 - 90 P.P.M.--about twice that at Jamaica--it is necessary during warm weather to reduce the sludge age to 0.2 days while Jamaica sewage works well at 0.4 days sludge age. In thus reducing the solids level we must accept removals of suspended solids at Owls Head at 73% as compared to the 83% at Jamaica. At Bowery Bay under hot weather conditions, treating a difficult sewage, excessive sphaerotilus growths were controlled for the critical period by moderate chlorination of the return sludge.

It will be seen from the foregoing that while the process has rather spectacular advantages in first and in operating costs that its use with unusual sewages calls for exact control and knowledge of its vaguaries. Our Treatment Section under Wilbur N. Torpey has done must to define its limitations and control. More will undoubtedly be learned about it.

For us it has proved to be a most useful method. At four of our plants where step aeration is provided it can be used at option to adjust for seasonal

requirements, compensate for temporary air limitations or where maintenance may preclude complete treatment. At the Owls Head and Rockaway plants, designed for its use alone, the results are acceptable and exceed all required standards for receiving waters.

Typical results secured at a number of our plants are shown in Table IV.

The third and final method that will be touched upon is a new one with us and is called "Activated Aeration" by Mr. Chasick, who devised the method. This procedure is for use in parallel with full activated sludge--either conventional or step aeration. In essence, it consists of introducing the waste sludge from an activated sludge battery to the head of another battery and aerating it there with sewage. The excess sludge from the activated sludge battery and that accumulated in the activated aeration battery is not returned but concentrated and removed.

Our only experience is at Wards Island. Here we have four identical batteries and for the past several months one battery has been operating on "Step Aeration," wasting its sludge to another battery employing "activated aeration" while the two other batteries use "modified aeration." Comparative results are shown in Table V. It will be noted that the results of the "activated aeration" battery are better than for "modified" batteries. The waste sludge, however, is somewhat less dense but still better than the waste sludge for step aeration. Air requirements are extremely low being less than .2 cubic feet per gallon.

Averaging the results of the "activated aeration" and its companion the "step" battery it will be seen that the overall results are superior to the "modified" batteries and the air use only slightly more. This combination of full activated sludge treatment and the reuse of its excess sludge to partially treat a like amount of sewage has interesting possibilities yet to be fully explored. It would seem to offer economy in overall treatment costs in respect to removals. Where sewages are difficult to treat by the "modified" method because of high filtrate B.O.D. the new combination of the stable "step aeration" method and "activated aeration" with no return of sludge in the latter may be of interest.

In presenting typical operating results of the three types of treatment we have discussed, the results shown are as they are tabulated in our operating records. They include, for example, the effluents of sludge thickening tanks, inferior effluents caused by temporary upsets in final settling tanks resulting from sudden changes in salt water infiltration, the failure of adequate sludge removals at times because of fog or other maritime conditions, and the normal imperfections of men and equipment.

Over the 14 years of practical operation and development of our new methods for complete treatment I have become convinced that the full treatment that can result from activated sludge methods can be secured safely and in much smaller installations than are currently being required by some regulating bodies. Please let it not be inferred that I advocate a 2.5 hour aeration period such as was used in the example in Table III. There are other considerations. For example, if a particular sewage requires high air use it will be necessary to build large enough aerators so that the requisite rate of air use can be applied economically. Basic methods are available for a more rational approach to aeration problems and it is hoped that they will find more general application.

The methods for intermediate treatment that are in use are relatively new and their full possibilities and limitations have not yet been completely explored nor methods of control fully developed. For sewages such as we have at

Jamaica, and which must be typical of many others throughout the country, the method of modified aeration has been eminently satisfactory and economical. Its economy is always outstanding. With more difficult and perhaps atypical sewages such as have been found at Owls Head and Bowery Bay the margin of control for satisfactory results is much more delicate. For major installations the working out of the necessary controls is well worth the effort because of the large stakes involved. We have here in "Modified Aeration" a most valuable tool to add to the kit of the sanitary engineer.

The foregoing summary of sewage aeration practices in New York City has necessarily been abbreviated--perhaps additional points can be brought out in the discussion to follow. Our developments here have gone beyond accepted practices elsewhere and it may be that some have not fully understood what we have been doing. It is believed that basic methods have been developed that have saved the city many millions of dollars in construction and operating costs. Perhaps more importantly we have been able to furnish higher forms of treatment on the limited sites that are available for our use.

TABLE I

MAJOR ELEMENTS OF NEW YORK CITY ACTIVATED SLUDGE PLANTS

Plant	Design Capacity (m.g.d.)	Placed in Operation	Detention Period (hr.) Primary Tanks[1]	Detention Period (hr.) Aeration Tanks	Detention Period (hr.) Final Tanks[1]	Final Tanks Overflow (g.p.d./sq.ft.)	Designed for
Wards Island	180	1937	1.23	6.58[2]	3.08	742	Conventional Activated Sludge
	240	1949	0.92	4.20[2]	2.31	990	Step Aeration[4]
Tallmans Island	40	1939	1.00	3.36[2]	2.61	792	Step Aeration
Bowery Bay	40	1941	1.00	2.42[2]	2.14	996	Step Aeration[4]
Jamaica	65	1943	None	2.44[2]	3.02	720	Step Aeration[4]
26th Ward	60	1951	1.51	3.32[2]	2.24	975	Step Aeration[4]
Hunts Point	120	1952	1.25	3.00[2]	2.50	1000	Step Aeration
Owls Head	160	1952	None	1.9[3]	1.7	1280	Modified Aeration
Rockaway	15	1952	None	2.0[3]	2.0	1150	Modified Aeration

1 at 100 per cent flow

2 at 125 per cent flow

3 at 110 per cent flow

4 provisions made for optional use of modified aeration.

TABLE II

CONTROL OF AERATOR EFFLUENT CONCENTRATIONS TO ADJUST FOR SLUDGE INDEX

Aerator Detention— 2.5 hours (nominal) with 25% Return Sludge

Sludge Age— 3.5 days for 100 P.P.M. Suspended Solids in Applied Sewage

Mode of Sewage Addition	Average Suspended Solids in Aerator P.P.M.	Suspended Solids - P.P.M. in Designated Pass				Allowable Sludge Index for 20% Cylinder	
		A	B	C	D	Donaldson S.D.I.	Mohlman S.V.I.
100% A Pass	2,700	2,700	2,700	2,700	2,700	1.35	74
25% A,B,C,D	2,700	4,150	2,800	2,130	1,720	0.86	116
33% B,C,D	2,700	5,500	2,460	1,590	1,200	0.60	167
20% B, 40% C & D	2,700	5,200	2,900	1,580	1,120	0.56	179
50% C & D	2,700	4,220	4,220	1,460	900	0.45	222
25% C, 75% D	2,700	3,950	3,950	2,020	880	0.44	227
100% D	2,700	3,340	3,340	3,340	780	0.39	256

TABLE III

TYPICAL RESULTS TREATMENT BY "STEP AERATION"

Plant	Period	Sewage Flow M.G.D.	Air Ratio c.f./gal.	Aeration Period Hours*	Overflow Rate Gals./ Sq.Ft. Day	Sludge Age Days	S.S. in Aerator Effluent P.P.M.	Raw Sewage P.P.M.		Final Effluent		Removals Percent	
								S.S.	B.O.D.	S.S.	B.O.D.	S.S.	B.O.D.
Wards Island	Oct.52-July 53	48**	.66	2.7	930	3.4	1100	154	139	8	7	95	95
Hunts Point	Sept.52-July 53	101	.50	2.6	980	4.1	900	135	138	9	10	93	93
Tallmans Is.	Year 1952	29	.49	4.7	1100	5.7	950	148	122	17	11	89	91
Bowery Bay	Summer 1953	41	.98	2.4	1020	4.3	1100	140	148	18	19	87	87
26th Ward	Summer 1953	44	1.05	4.3	710	4.6	1050	143	132	19	16	87	88

*Calculation based on conventional activated sludge flow

** Battery C only

TABLE IV

TYPICAL RESULTS OF TREATMENT BY "MODIFIED AERATION"

Plant	Period	Sewage Flow M.G.D.	Air Ratio C.F./ Gal.	Aeration Period Hours	Overflow Rate Gals./ Sq.Ft. Days	Sludge Age Days	S.S. in Aerator Effluent P.P.M.	Raw Sewage P.P.M. S.S.	Raw Sewage P.P.M. Total B.O.D.	Raw Sewage P.P.M. Filt. B.O.D.	Final Effluent P.P.M. S.S.	Final Effluent P.P.M. Total B.O.D.	Final Effluent P.P.M. Filt. B.O.D.	Removals Percent S.S.	Removals Percent Total B.O.D.	Removals Percent Filt. B.O.D.
With Primary Settling																
Wards Island	Year to Apr. 53	58	.34	2.6	1030	0.17	150	153	139	41	35	38	22	77	73	46
26th Ward	Year to Apr. 53	41	.55	2.6	670	0.24	190	153	109	44	37	36	17	76	67	61
Bowery Bay	10 Mo. to Feb. 53	41	.45	2.8	1070	0.25	190	147	165	64	47	65	35	68	61	45
Without Primary Settling																
Owls Head	Year to July 53	85	.49	2.3	790	0.23	360	160	170	75	43	71	42	73	58	44
Jamaica	Year 1952	51	.33	1.6	830	0.40	850	168	109	34	28	26	13	83	76	62
Rockaway	July-Aug.53	18	.34	1.6	1380	0.59	990	119	105	35	40	38	10	66	64	72

TABLE V

COMPARISON OF STEP AERATION, ACTIVATED AERATION AND MODIFIED AERATION

IN

PARALLEL OPERATION AT WARDS ISLAND SEWAGE TREATMENT WORKS

FEBRUARY - JULY 1953

Type of Treatment	Sewage Flow M.G.D.	Air Ratio C.F./ Gal.	Aeration Period Hours	Overflow Gals./ Sq.Ft./ Day	Excess Sludge % Solids	Raw Sewage P.P.M.		Final Effluent P.P.M.		Removals Percent	
						S.S.	B.O.D.	S.S.	B.O.D.	S.S.	B.O.D.
1. Step Aeration	47	0.61	2.7	880	-	162	133	7	6	96	95
2. Activated Aeration	56	0.19	2.8	1100	3.5	162	133	28	32	83	76
Average 1 & 2		0.38						18	20	89	85
3. Modified Aeration	55	0.29	2.7	970	4.6	162	133	35	42	78	68